

Sagebrush and Mine Reclamation: Whats Needed From Here?

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Abstract

The Wyoming Environmental Quality Act requires coal mines to include shrubs in the reclamation revegetation species mix and further specifies planting patterns and density required to achieve full reclamation bond release. Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is a principal shrub component in many of the vegetative communities found in the coal mining districts of Wyoming and elsewhere in the western United States. Efforts to establish Wyoming big sagebrush on reclaimed areas by the coal mining companies in Wyoming have met with mixed success. The University of Wyoming, through its Abandoned Coal Mine Lands Research Program funded by the Abandoned Mine Land Division of the Wyoming Department of Environmental Quality, has sponsored several research projects beginning in 1991 to better understand the requirements of Wyoming big sagebrush revegetation and to find more cost effective and dependable methodologies for meeting the legislative and regulatory requirements. The research to date has been less than conclusive; seed is germinating, but seedlings seldom reach a mature, dominant, or co-dominant position on reclaimed sites. One study found natural sagebrush stands are even-aged, suggesting only certain, unique climatic or weather conditions may be a requisite for stand establishment, or perhaps some catastrophic event such as fire, may be required. Further research is needed to find economic methods for Wyoming big sagebrush establishment and survival. Current seeding methodologies may add as much as five cents to the cost of producing one ton of coal. Coal contracts are won or lost by as little as five cents subtracted or added to the cost per ton of coal. What are the economic cut-offs for “transplanting and seeding”? What types of cultural practices will ensure seed germination and seedling survival each year, instead of just when climatic conditions are ideal? Cultural practices may include, but are not limited to soil chemical and physical characteristics, surface manipulation, mulches, cover crops and heavy livestock grazing. This information is needed before the mining industry can satisfy the regulatory requirements in a cost-effective manner.

Introduction

The Wyoming Environmental Quality Act at § 35-11-415(b)(vii) requires mine operators to “Replace as nearly as possible, native or superior self-regenerating vegetation on land affected, as may be required in the approved reclamation plan” (WEQA 1998). The Land Quality Division of

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the Wyoming Department of Environmental Quality promulgated rules and regulations in 1996 specifying a shrub standard to be achieved as part of the revegetation success requirements for coal mines seeking reclamation bond release. Chapter 4 of the Rules and Regulations, “Environmental Protection Performance Standards for Surface Coal Mining Operations,” at Section 2 (d)(i) requires the operator to “...establish on all affected lands a diverse, permanent vegetative cover of the same seasonal variety native to the area or a mixture of species that will support the approved postmining land use in a manner consistent with the approved reclamation plan. The cover shall be self renewing and capable of stabilizing the soil.” Section 2 (d)(x)(E) further requires “The post mining density, composition, and distribution of shrubs shall be based upon site specific evaluation of premining vegetation and wildlife use. Shrub reclamation procedures shall be conducted through the application of best technology currently available.” Finally, Subsection 2 (d)(x)(E)(I) states “Except where a lesser density is justified from premining conditions in accordance with Appendix A, at least 20% of the eligible lands shall be restored to shrub patches supporting an average density of one shrub per square meter. Patches shall be no less than .05 acres each and shall be arranged in a mosaic that will optimize habitat interspersion and edge effect.... This standard shall apply to all lands affected after August 6, 1996” (LQD 1998). Although big sagebrush (*Artemisia tridentata*) and its subspecies are not specifically mentioned in the above cited requirements, because of the requirements to replace or restore the vegetation existing prior to the mining disturbance, the replacement of big sagebrush is specified by default.

The coal mining industry has included sagebrush in its revegetation efforts for the past decade with mixed success. Schuman and Booth (1998) and others have suggested the cause for the mixed results may be low seedling vigor, competition from herbaceous species, altered soil conditions, and reduced levels of arbuscular mycorrhizae in the reclaimed mine soils.

Recent Big Sagebrush Establishment

The Abandoned Coal Mine Land Research Program (ACMLRP), administered by the University of Wyoming and funded by the Abandoned Mine Land Division of the Wyoming Department of Environmental Quality, was established in 1991 to sponsor research for abandoned and active coal mine reclamation. The ACMLRP has funded four research projects on big sagebrush establishment, with emphasis on the subspecies *wyomingensis*. Four major studies have been undertaken since 1991, three of which have been completed and one is still in progress.

One study, “Climatic Control of Sagebrush Survival for Mined-Land Reclamation” (Perryman et al. 1999), looked into climatic and environmental factor relationships with natural sagebrush stand establishment. This study evaluated stands of the Wyoming, basin (*vaseyanna*), and mountain (*tridentata*) subspecies from locations throughout Wyoming. Significant findings include stands are generally even-aged and establishment is episodic. Mean stand ages of Wyoming big sagebrush in northeast and central Wyoming are approximately 26 to 32 years. This is 3 to 4 times older than the mean fire-free interval of 8 years for these areas. Irregular pulses of recruitment appear to be characteristic of big sagebrush stands in Wyoming.

This study further found that above average December and January precipitation following initial establishment of Wyoming big sagebrush seedlings was a common occurrence associated with stand establishment. It would appear that the deeper snow cover associated with the above-average

precipitation at that time of year provides protection from winter desiccation as well as additional soil moisture during the spring growing season. For basin big sagebrush, there was higher recruitment in those years with higher than average June precipitation during the first growing season, followed by higher than average precipitation in March, May and June of the second growing season. Mountain big sagebrush did not follow this pattern as precipitation in the higher mountain environments means lower temperatures, not conducive to germination and growth at those times of the year.

Perryman et al. (1999) further found that big sagebrush stand age might be estimated by stem diameter measurements of the larger plants within the stand with reasonable accuracy. They obtained good correlation with approximately 1 mm of stem diameter per year.

A second study, “The Influence of Post-harvest and Pre-planting Seed Treatment on Sagebrush Seedling Vigor,” was initiated in 1993 (Booth et al. 1996). Analyses were performed on big sagebrush seeds collected from several locations during the late winter. Processing through a 48-inch commercial debearder did not appear to reduce seed quality. Moisture percentages in the seed ranged from 2.3 to 9.0% and seed weights ranged from 0.022 to 0.032 g/100 seeds. Germination percentages were highest, and germination most rapid, from the heavier seeds.

This study also evaluated moisture uptake (hydration) by big sagebrush seed in storage during a 15-day period at 2°, 5°, 10°, and 15°C. Hydration occurred slowly at the cooler temperatures while the maximum rate of hydration occurred at 10°C. The differences in hydration rates did not appear to influence sagebrush seed germination or seedling vigor in laboratory tests.

Big sagebrush seeds, when exposed to seven water potentials ranging from 0.00 to –1.5 MPa, exhibited greatest germination at 0.00 Mpa. The authors also observed that the pericarp reduces water uptake and that pericarp removal enhanced germination between –0.50 and –1.00 Mpa. Booth et al. (1996) recommended, however, not to remove the pericarp, as they believed it is important in retaining seed viability in the soil until more favorable soil moisture conditions occur. They implied normal seed processing would result in an adequate quantity of naked seed without the need for further pericarp removal.

As an extension to the previous study, Booth et al. (1998) in “Wyoming Big Sagebrush Seed Production from Mined Lands and Adjacent Unmined Rangelands,” evaluated big sagebrush seed production from reclaimed coal mine lands and undisturbed, native ground. This study was done at the Dave Johnson Coal Mine in central Wyoming from July 1995 through October 1998. Big sagebrush plants observed ranged in age from 10 to 20 years. They found the number of seed stalks per plant, seed quantities, and seed weights were greater from plants on reclaimed mine land than from comparison plants on adjacent undisturbed sites. Some plants had been fenced to observe the effects of wildlife browsing. It was observed that the unfenced plants produced lighter and drier seeds than the plants that were fenced. It was also observed, unexpectedly, that the fences apparently provided some environmental modification comparable to the effects of mulch and wind protection treatments applied as part of the study. Soil moisture conditions varied considerably from year to year. However, when averaged across all variables, soil moistures on reclaimed and mulched native sites was higher than on no-mulch reclaimed and no-mulch undisturbed sites.

In the study “Strategies for Establishment of Big Sagebrush (*Artemesia tridentata* ssp. *Wyomingensis*) on Wyoming Mined Lands” initiated in 1991, Schuman and Booth (1998) looked at coal mine reclamation practices and their relationships with big sagebrush establishment. They found that direct placed topsoil did not act as a seed bank for big sagebrush as compared to

stockpiled topsoil. They did find, however, that direct placed topsoil consistently had higher soil moisture and greater arbuscular mycorrhizae spore counts than did stockpiled topsoil. As a result, the direct placed topsoil sites had 40% more big sagebrush seedlings than stockpiled topsoil sites the first season of establishment and from one to two orders of magnitude more the following season.

Schuman and Booth (1998) looked at the differences in mycorrhizal infection between direct placed topsoil and stockpiled topsoil. In spite of a nearly 33% greater spore count in direct placed topsoil, there was no apparent difference in the number of mycorrhizal infected big sagebrush seedlings between the two soil treatments. The authors note this may be because the non-infected seedlings had already died prior to the observations. There was a positive effect of mycorrhizae on drought stress tolerance by big sagebrush seedlings (Stahl et al. 1998).

Stubble mulch and crimped straw mulch were found to provide greater big sagebrush seedling establishment than was no mulch or stubble and straw mulch together. Grass competition was further observed to have reduced big sagebrush seedling density throughout the duration of the Schuman and Booth study.

A final aspect of the study, “Strategies for Establishment of Big Sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) on Wyoming Mined Lands,” was to study the relationship and effect of seeding fourwing saltbush (*Atriplex canescens*) as a pioneer species for later big sagebrush establishment. There were no effects, either positive or negative, shown by this phase of the study. It was observed, however, that the increase in total shrub density was favorable in helping to meet the shrub density regulatory standard for reclamation bond release.

An important finding from the Schuman and Booth study is that big sagebrush seed apparently maintains its viability for a much longer time than previously thought. New seedlings were noted three and five years after the initial seeding.

The study “Grass Competition and Sagebrush Seeding Rates: Influence on Sagebrush Seedling Establishment” (Fortier et al. 1999) is in its first year and only preliminary results are reported. First growing season data for big sagebrush seedling performance under three sagebrush seeding rates and seven grass seeding rates were mixed. Heavy spring and early summer precipitation masked the expected effects of increasing grass competition. However, big sagebrush seedling density did show a direct relationship with seeding rates, and big sagebrush seedling density was lower at the higher grass seeding rates. Big sagebrush seedling density declined with decreasing precipitation and soil moisture content throughout the summer for all seeding rates, and the greatest seedling loss was seen in the highest big sagebrush seeding rates. All three big sagebrush seeding rates of 1 kg/ha, 2 kg/ha, and 4 kg/ha met the regulatory required density of 1 shrub per square meter at the end of the first growing season.

Summary

The research conducted under the Wyoming ACMLRP has shown that the establishment of natural big sagebrush stands is episodic and appears to be dependent upon winter and early spring precipitation patterns immediately following seedling establishment. Other findings of significance are:

Big sagebrush seedlings are sensitive and susceptible to winter desiccation.

Big sagebrush seedlings are sensitive to late growing season moisture stress.

Big sagebrush seedlings are intolerant of grass and/or herbaceous competition, apparently for the above stated reasons.

Direct placed topsoil is not an apparent source of big sagebrush seed or propagules.

Mycorrhizae are important in helping big sagebrush seedlings survive periods of moisture stress.

Direct placed topsoil generally has higher soil moisture content and mycorrhizal spore counts, both of which are beneficial to big sagebrush seedling establishment and survival, than does stockpiled topsoil.

Big sagebrush should be seeded a season or two before herbaceous species or to seed herbaceous species at a lower rate than typically used to aid sagebrush seedling establishment.

Stubble mulch or straw mulch provides protection to big sagebrush seedlings from winter desiccation and to maintain soil moisture contents for longer periods of time.

Big sagebrush seed has an apparent longer viability than previously thought, up to three to five years.

Research Needs

Further research is needed to find cost-effective methods for Wyoming big sagebrush establishment and survival. Current seeding methods, following many of the preceding recommendations, may add as much as \$0.05 per ton (\$0.055 per metric ton) of coal produced, which is substantial considering that Powder River Basin coal is selling on the spot market for less than \$3.50 per ton (\$3.85 per metric ton). Contracts are won or lost by as little as five cents per ton of coal.

Transplanting and seeding costs are a substantial part of the total reclamation costs. The cost of transplanting containerized stock can be more than \$2.00 per stem. It would require 809 stems per acre (2,000/ha) or \$1,618.00 per acre (\$4,000/ha) to meet the regulatory requirement of one shrub per square meter over 20% of the area just for planting only the big sagebrush.

Seeding costs are much less than transplanting but at a much greater risk of establishment failure. One 1999 contracted seed price for Wyoming big sagebrush was just over \$32.00 per PLS pound (\$70.40/kg). At a seeding rate of one-half pound PLS per acre (0.625 kg/ha), the cost for the seed alone would be \$3.52 per acre (\$8.80/ha) for the shrub density requirement of 20% of the area. This does not include the cost of planting, which, when including seedbed preparation, seeding, and mulching, will approach \$500.00 per acre (\$1,250.00/ha). Recent research has been recommending 3-8 PLS pounds per acre (3.4 – 9.1 kg/ha) seeded for best results. Six PLS pounds/acre (6.82 kg/ha) of big sagebrush seed at the current price is \$192.00 per acre (\$480.00/ha) or \$38.00 per acre (\$96.00/ha) plus seeding costs for 20% of the area. It is clear the costs of planting materials alone for big sagebrush become quite high considering the establishment success that has been achieved. It is imperative to find more efficient and cost-effective ways of meeting the shrub density and vegetative performance requirements of the Wyoming Land Quality Division's Coal Rules and Regulations.

Next Generation of Research

Research in two basic areas is needed. Are there new cultural practices for establishing big sagebrush that have not yet been explored? What are the costs and economics of those cultural practices and methodologies that are, or will be, proven to result in big sagebrush stand establishment? How can these costs be improved?

Different types of cultural practices to ensure seed germination and seedling survival each year should be explored. Cultural practices may include, but are not limited to, soil chemical and physical characteristic modifications, surface manipulation, mulches, cover crops, and even heavy livestock grazing.

What are the soil chemical characteristics that drive big sagebrush germination and establishment? Are there nutrient characters such as organic matter or nitrogen that aid in the growth of big sagebrush? What are the soil physical characteristics or surface manipulation that will increase water holding capacity until such a time that the seed needs it to germinate or seedlings need it to continue growth and survival? Can the use of mulches and cover crops be used more effectively to increase soil moisture and protect new seedlings? We know that heavy livestock grazing will inhibit grass growth and allow sagebrush to increase. Can grazing be utilized to speed up the process of sagebrush establishment?

Only a few ideas have been given for future research that may provide those of us in the industry with the knowledge needed to make good decisions. Western coal is a very competitive business and new and more cost-effective ways of competing must be found if the coal business is to survive. Finding better, more dependable, cost-effective ways to successfully establish big sagebrush is one very important way to remain competitive while maintaining compliance with the reclamation regulations.

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